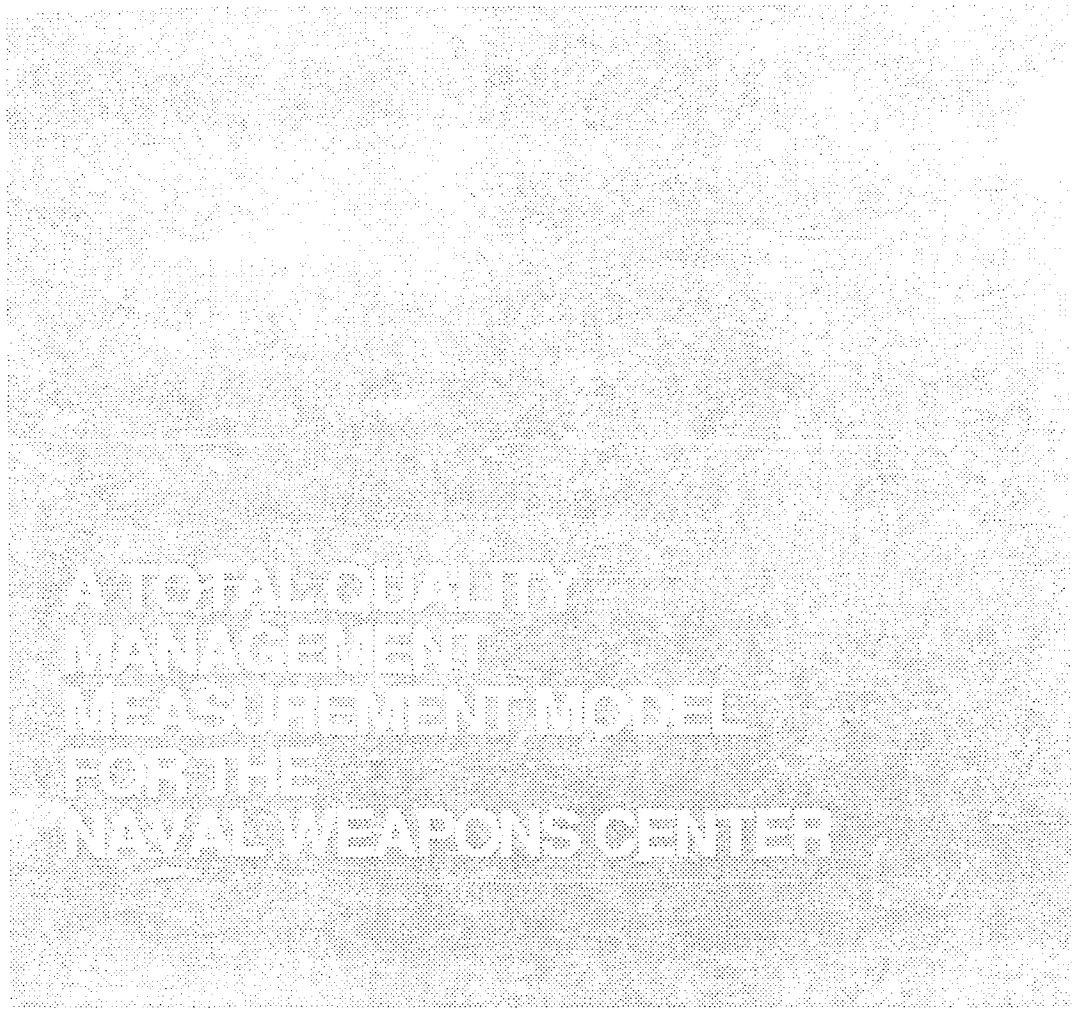
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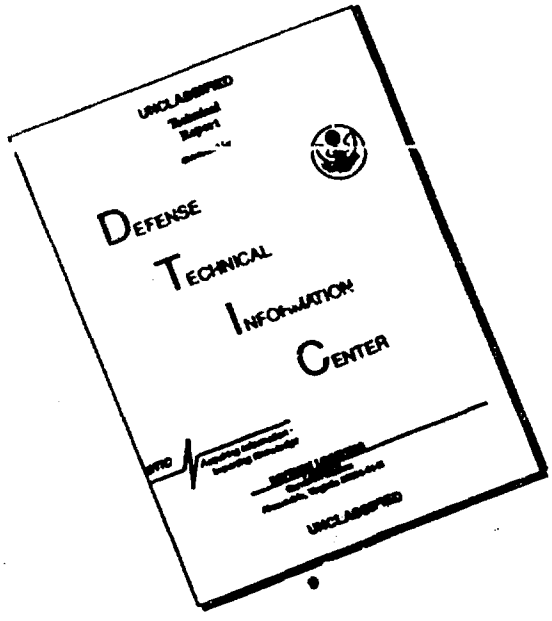
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FOREWORD

This report is the result of research conducted from August to December 1990 at the Naval Weapons Center, China Lake, California. This work was funded by the Quality and Productivity Improvement Directorate and is part of a comprehensive program aimed at implementing the principles of total quality management in the execution of the Center's mission.

DILLARD BULLARD, Head
Quality and Productivity Improvement Directorate
8 February 1991

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The author is indebted to the staff of Qualtec, Inc., West Palm Beach Gardens, Florida, for its generous sharing of information on quality-measurment modeling, and to the many China Lakers who continuously surpass the expectations of their jobs to offer help and share information.

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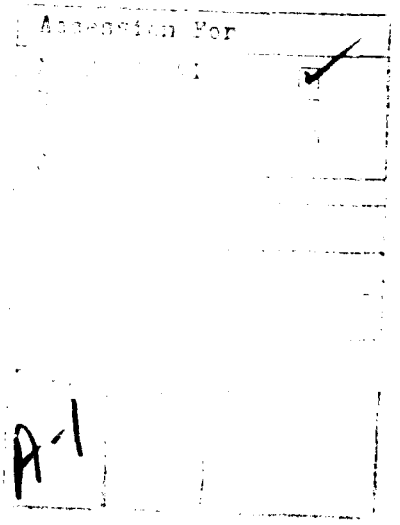
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ABSTRACT

The author's task, assigned by the Head of the Quality and Productivity Improvement Directorate, was to find a method for choosing the measures of effectiveness for the Naval Weapons Center. This report describes the architecture for a total quality management measurement model that provides a vehicle for identifying the critical measures of effectiveness for NWC. The report is a synthesis of information gleaned from the literature and especially from consultation with Qualtec Inc., West Palm Beach Gardens, Florida, the consulting arm of Florida Power and Light.



INTRODUCTION

Many of the key elements necessary for total quality management (TQM) already exist at the Naval Weapons Center (NWC). For instance, NWC already has a vision statement, a philosophy statement, a definitive mission statement, and a commitment "to excellence through teamwork and innovation." Many processes and procedures are in place, and a multitude of measurements are already reported both internally and externally. Additionally, some formal and informal surveys of customers and employees are performed on and off Center (NWC, July 1990). Many important ingredients, such as individual commitment, task teams, and especially attention to customers have long been NWC standards (NWC, 1968).

This report describes a TQM measurement model that can realign the existing elements, processes, procedures, and measurements into a new way of using the available information. The potential benefits are numerous. Firstly, the model provides a way to use the existing system. Secondly, the model easily allows the definition of new measures, if necessary. Thirdly, the model provides a mechanism through which priorities can be advertised throughout the organization. Fourthly, the model offers a means by which the accumulated improvements of products by employees can be collectively analyzed to show response to the customers' expectations.

Most importantly, this model allows the definition of customer requirements in terms of the technical functions performed by NWC employees, and the prioritizing of these functions from a customer perspective. The best possible trade-off of all requirements can be attained, which is an especially important factor when one considers that some requirements directly conflict with one another.

This measurement model can create a framework for consistent language and communication throughout the Center. It can create an arena that allows efficient flow-down of mission and policy and efficient flow-up of results. That is, the mission of the Center can be deployed throughout the Center. Implementing this measurement model will encourage the realization of TQM at NWC.

DESCRIPTION OF THE TQM MEASUREMENT MODEL

BASIC DESIGN

The TQM measurement model is organized by broad functional categories. This structure minimizes the overlap that would result from categorizing by organizational units (Qualtec). Many functions are similar from unit to unit. The elements of the model are shown in the foldout diagram on page 39 and are discussed below.

The basic design of the model is the same at all levels. The whole organization can use the same model for determining priorities from a customer perspective. This consistency contributes to flow-down of mission and policy and flow-up of improvement effects; that is, a common measurement system contributes to consistent communication at all levels of management and across all organizational lines.

PRODUCTS

NWC products and services include major technical programs, test and evaluation activities, manufacturing technology and production support, research, development, and all of the services that support these activities (NWC, July 1990).

CUSTOMERS

Four types of customers must be considered. Internal customers tend to be those who work on different phases of a product. External customers tend to be those off-Center groups that use an end product. Direct customers are those who buy and use a product, and indirect customers influence how business is done.

NWC's direct external customers are its sponsors in Washington that provide the funding for the RDT&E projects (NWC, July 1990). Indirect customers are the various government agencies that dictate business practices; the regulatory agencies that act in the interest of the public; and, in particular, the taxpayers.

CUSTOMER REQUIREMENTS

Customer requirements are the needs and wants of the customer expressed in terms of specifications mutually agreed upon by the customer and NWC. Some requirements are imposed. Communication with customers should produce a list of valid requirements that are current, realistic, and measurable; that meet reasonable expectations of the customer; and that fall within corporate constraints.

The customer requirements will generally address areas of concern such as performance, conformance, durability, affordability, and cost. Appendix A lists several possible requirements and their definitions.

CATEGORIES

All customer requirements can be partitioned into the following categories (Figure 1):

- Quality (customer support; direct contact with customer)
- Deliverables (basic product or service to customer)
- Cost (financial management)
- Safety/Security (protection of life and property)
- Corporate Responsibility (concern for community)

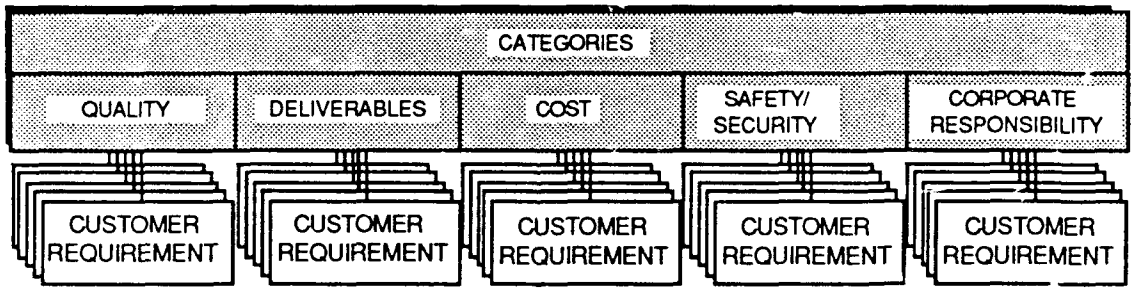


FIGURE 1. Categories.

The functions of an organization (those activities and processes that, in the aggregate, compose the daily work of the organization) can also be partitioned into these same categories. Thus all requirements and their corresponding NWC activities are categorized in the same way.

Each category must show continuous improvement. With limited resources to distribute among the categories, each department and organizational level must have an understanding of priorities from the customer perspective in order to maximize resource allocation.

NWC ACTIVITIES

NWC activities (Figure 2) are the functions within NWC that best represent the customer requirements. Each category of the measurement model has several NWC activities.

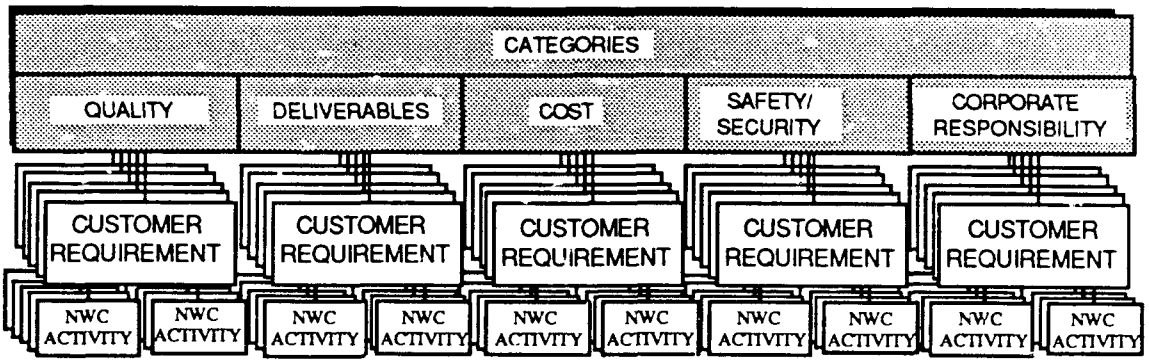


FIGURE 2. NWC Activities.

The relationship of each requirement to one or more activities must be established. That is, requirements must be correlated with the way business is done at NWC, according to the best in-house judgement. Put another way, requirements are expressed in terms of operational definitions (Kirkham). These defined relationships determine the NWC activities.

For example, if a customer requirement is ethical/legal integrity, then one NWC activity could be addressing equal employment opportunity issues If system reliability is a requirement, then some NWC activities could be program management, design analysis, parts control, development testing, and environmental stress screening.

Each activity is the NWC function that best represents a customer requirement. A Quality Table (Table 1), described later in this report, offers a mechanism for matching these functions and requirements.

MEASURES

Measures (Figure 3) are the graphic displays of the outputs of the NWC activities or functions. Measures are subdivisions within NWC activities that best reflect each activity. Each activity can have several measures. See Appendix B for a discussion of suggested measures appropriate for a research-and-development environment.

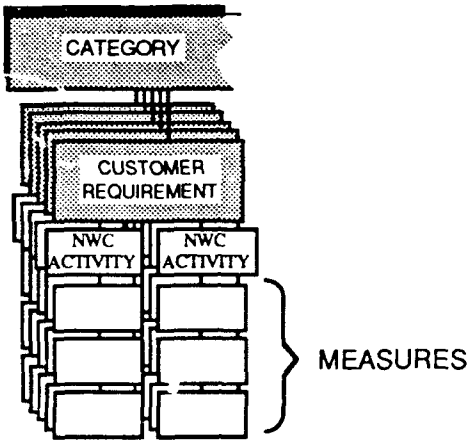


FIGURE 3. Measures.

Superimposed on any measure graph is the desired target value (Figure 4). Target values are goals that are mutually and interactively established between the customers and NWC. Selection of a target value provides a way of establishing a baseline, demonstrating the gap between what is and what should be, and tracking changes and improvements over time. Therefore, measures become graphic displays of the degree to which conformance to customer requirements is being effected.

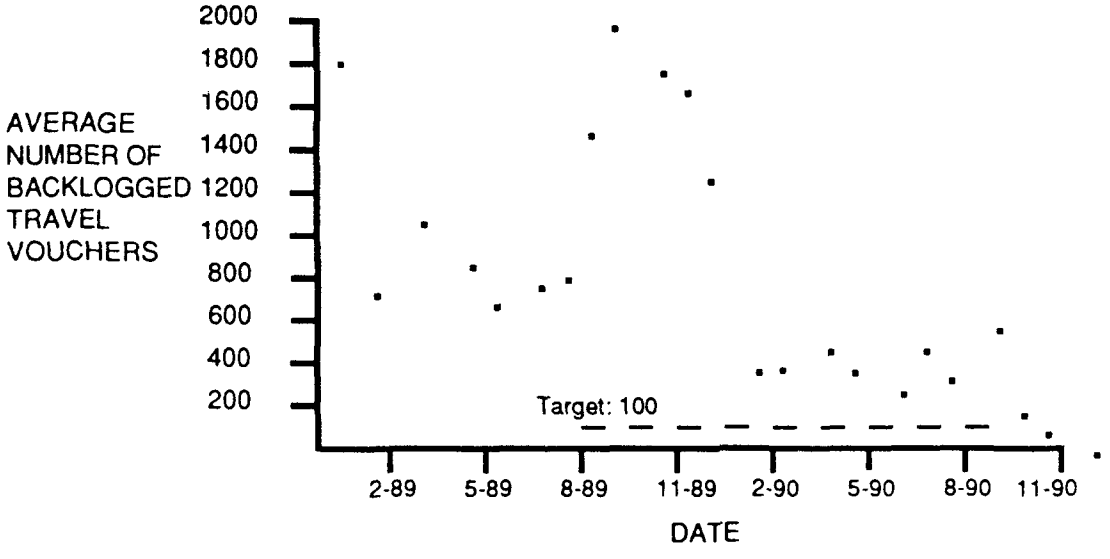


FIGURE 4. Typical Measure With Target Value.

OWNERS

An NWC owner (Figure 5) is the individual (or small group) with the primary responsibility for an NWC activity that reflects a particular customer requirement. The owners are responsible and accountable for the many intermediate products and processes that eventually are combined into the collective products of NWC as a whole. The daily output of owners produces the information that is reflected in the graphic measures. Each owner contributes in a different way. See Appendix C for a discussion about criteria for choosing measures and how owners can contribute.

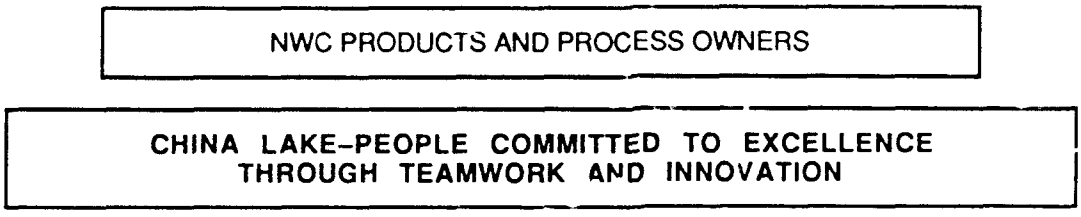


FIGURE 5. Owners.

Individual commitment to excellence is the turning point that transforms the flow-down part of mission and policy deployment throughout the organization into the flow-up part of quality improvement.

SURVEYS

Sample surveys provide data for assessing attitudes and making decisions (Dunham). Properly designed surveys capture information that reflects preferences of those queried (Fienberg). Appendix D contains additional information concerning what constitutes a good survey, the use of surveys by Florida Power and Light, and additional sources of information about particular types of surveys.

QUALITY TABLES

The primary Quality Table (Table 1) shows a suggested categorization of customer requirements. Table 2 shows a suggested breakdown in two categories with sample activities including measures that represent these sample activities. Supplementary tables can be used for the customer to weight the requirements and for NWC to rank each customer by an importance factor according to how much business or influence that customer has.

TABLE 1. A Typical Quality Table.

Category	Customer Requirements	NWC Activities	Measures
Quality	Accuracy Timeliness Completeness Clarity Accountability Responsiveness Effectiveness Efficiency Human factors engineering		
Deliverables	Functional performance Conformance to specifications Technical flexibility Support Durability Affordability Producibility Reliability Maintainability Environmental engineering Susceptibility Vulnerability		
Cost	Management Containment Innovation Efficiency Productivity		
Safety/Security	Public safety Employee safety Customer safety Product security		
Corporate Responsibility	Quality of worklife Concern for physical environment Concern for local communities Financial integrity Ethical/legal integrity		

Quality tables can be as simple or as complicated as necessary. A sophisticated table and software could be developed that would combine all correlation, weighting, and ranking factors into one function. An interactive, user-friendly database could be constructed so that employees involved with a particular product could access the data, contribute information, and get feedback.

TABLE 2. Sample Breakdown Within Quality Table.

Category	Customer Requirements	NWC Activities	Measures
Deliverables	Reliability	Design analysis	Existence of fail-safe systems Mean time between failures Mean time to first failure Failures per unit time
		Environmental stress screening and acceptance testing	Infant mortality rate Ratio of production failures to customer failures
		Parts control	No. of redesigns needed for nonprocurable parts No. of "off-Center" problem-solving trips
		Others	
	Maintainability	Requirements determination	Mean time to repair Ratio of maintenance workhours per operating hour Unplanned downtime
		Other activities	
Corporate Responsibility	Ethical/legal integrity	EEO issues	EEO Complaints – No. of informal complaints – No. of resolutions – No. of formal complaints Affirmative action – No. of minority/women hired – No. of handicapped hired – No. of minority/women promotions – No. of handicapped promotions – Special emphasis programs – Initiatives in the special emphasis programs
		Other issues	

SELECTING PRIORITIES

Prioritizing customer requirements is done through information obtained from customer surveys and from expert judgement within NWC. Customers can weight requirements according to their individual preferences. Combining weights yields a list of important requirements in descending order. NWC can rank its customers by an importance factor that numerically reflects the amount of product use by a customer or the influence that customer has over the Center's business.

This competitive evaluation of customer requirements yields pooled numerical results that indicate the best possible resource allocation for gaining the most impact toward improving products and services.

The entire collection of categories, activities, and measures stays basically the same after it is defined. Prioritizing the customer requirements yields the few activities that are selected for immediate improvement and points to their representative measures that can be closely monitored.

MEASURES OF EFFECTIVENESS

The measures of effectiveness are those few measures that, through the Surveys and priority selection just discussed, have been selected as best representing the priority customer requirements. These external and internal quality measures represent the "vital signs" of NWC. Focusing common efforts on improving these few measures yields the most impact towards improving the quality of NWC products.

These measures can be augmented by other measures as a more comprehensive reflection of quality efforts. Appendix E contains details.

SUMMARY

Customer requirements are weighted, ranked, and prioritized according to the customer surveys and expert judgement within NWC. The customers' preferences are taken into consideration, and conflicting impacts within NWC are also addressed.

The appropriate categories and NWC activities that best represent the priority requirements are identified. The measures within these activities that best reflect the customers' priorities are selected for immediate improvement. Short-term (and long-term) targets are set for these measures. These few measures become the priority list of quality measures (or measures of effectiveness), because improvements in these selected few should provide the most impact towards improving customer satisfaction (Figure 6).

The overall matrix of information tracked (categories, NWC activities, and measures) stays basically the same. All measures continue to be monitored, even though only a few need immediate improvement. As soon as priority targets are reached, these measures drop out of the priority list, and others are selected as priorities.

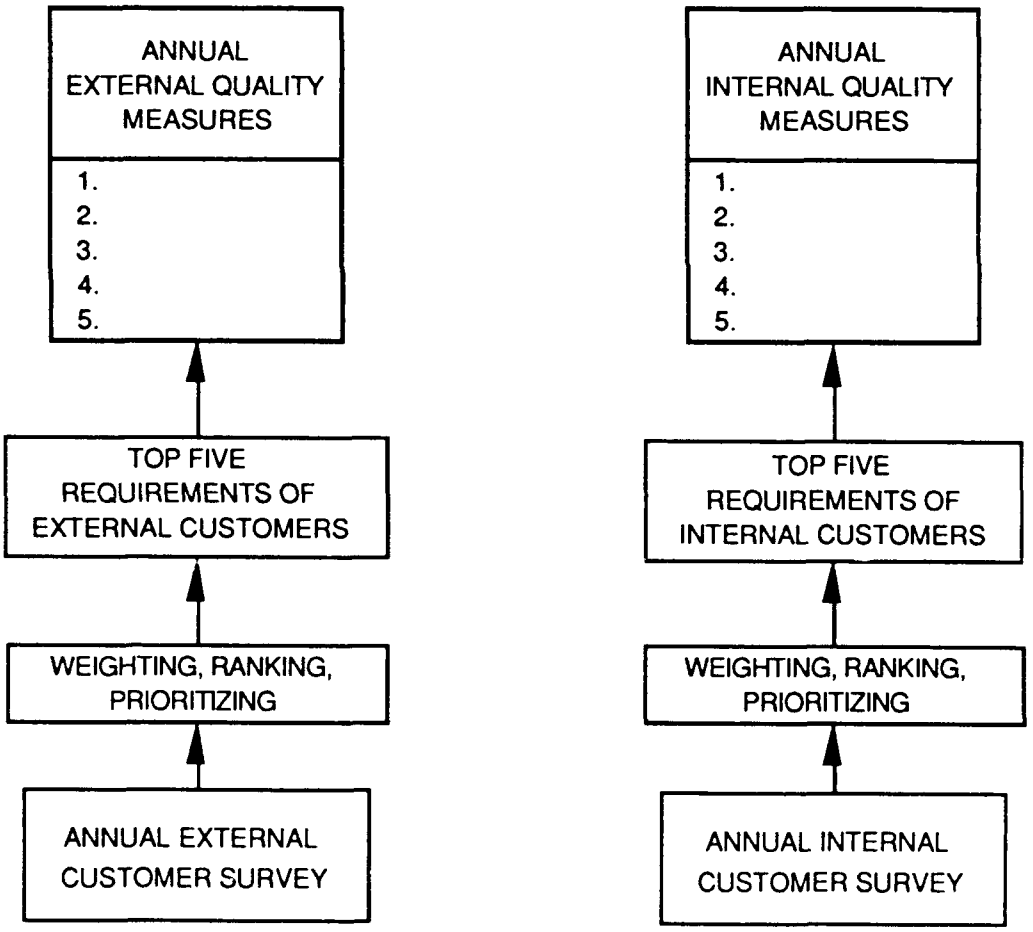


FIGURE 6. Generation of Measures of Effectiveness.

EVALUATION

VALIDATION

Florida Power and Light (FP&L) has for several years successfully used the model described in this report. FP&L is the first non-Japanese company to be awarded the Deming Prize by the Japanese Union of Scientists and Engineers. This award signifies the degree to which the Japanese were impressed with FP&L's ability to implement and maintain TQM. FP&L's measurement model has matured over the past few years into a very sophisticated "table of tables" for capturing the customer voice and translating it into business activities (Qualtec).

Historical data are available for most of the measures, so such data are amenable to formal statistical analysis any time the need should arise. Baselines for new measures can be established.

Although the assignment of priorities seems subjective, it is believed by experts that even subjective results can become objective standards that are measurable and statistically assessable (Garvin, Reid, Salvendy).

If the customer surveys are performed properly, the data gathered are also appropriate for formal statistical analysis (Fienberg). One can study trends, significant new events, and comparisons of new standards with previous standards. One can also gain additional insight by exploring a multitude of relationships in the information.

LIMITATIONS

The measurement model requires the development of a comprehensive and consistent method for surveying customer needs. This is a task that is routinely performed by many organizations, and there is a wealth of expert information available from many sources to assist in the development of valid and reliable survey models (Salvendy, Jessen). See Appendix D for more information.

Other modules of TQM need to be in place for most efficient use of the measurement model's capabilities. One necessary ingredient is an efficient employee-suggestion system. Another is training throughout NWC in several areas, such as systems engineering, mathematical modeling, and statistical training, to supplement TQM.

Commitment "to excellence through teamwork and innovation" is the cornerstone that makes TQM really work within this measurement model. However, scientific analysis and applications tools such as statistical process control, Taguchi methods, and other graphic problem-solving techniques need to be in place to capture and anchor individual commitment. Availability of these applications encourages proactive participation at all levels.

One frequent criticism of applying TQM in a research-and-development environment concerns the difficulty of quantifying productivity and creativity of scientists and engineers. To a degree, this criticism is valid. However, some approaches have been suggested in recent literature. Additionally, there are many ways to describe the factors that have contributed to the past and present success of NWC (NWC, 1968; NWC, August 1990). This wealth of information is readily available for examining our processes in more detail and identifying measures that can indeed represent or reflect creativity and productivity in an R&D environment. Several approaches are described in Appendix F.

CONCLUSIONS

The measurement model described in this report and shown in Figure 7 on page 39 represents a mechanism for more efficient deployment of the NWC mission statement throughout the Center. The model promotes the actualization of TQM by redefining activities within the organization in such a way that management captures the voice of the customer. Priorities flow down into sublevel functions, NWC resources are focused on the selected priorities, and employees know what is expected. Thus everyone in the organization has the opportunity to contribute immediately and positively to improvements that flow up into customer satisfaction with NWC products and services.

The benefits of accepting and applying this measurement model are potentially enormous. It provides a mechanism through which "the voice of the customer is captured and translated into the way business is done" (Qualtec) or, stated another way, through which customer requirements are equated to product characteristics (Reid). Through this model, TQM can be implemented with specific tools and perpetually maintained. The measurement model provides an architecture within which NWC can continually meet its customer needs and thereby guarantee continuing recognition as a quality organization.

RECOMMENDATIONS

It could be beneficial for NWC and Qualtec, Inc., to develop a working relationship for the exchange of information, ideas, and expertise. Florida Power and Light learned TQM methods directly from the Japanese and has successfully practiced TQM for several years. The consultants at Qualtec are some of the key personnel who nurtured FP&L employees through the transformation into an internationally recognized quality organization. NWC has achieved success in areas that are of interest to Qualtec, such as the extensive use and networking of personal computers.

The author recommends that every effort be made to implement the quality measurement model described in this report. An ideal approach would be to have a highly analytical individual, with the ability to relate to all levels of Center organization, oversee and implement an integrated effort that includes the iterative processes of customer surveying and prioritizing objectives within the Quality Table. A core group could be formed with representatives from each category with collective backgrounds in necessary disciplines such as mathematics, statistics, business, and engineering. This approach would help to ensure that surveying and prioritizing would overlap all functional areas within NWC.

Implementation of this measurement model through a concerted team effort by NWC workers and management alike under the leadership of a committed individual will help NWC evolve to a more advanced level of TQM. With implementation of this model, NWC will continue to be recognized as a master of innovation and successful implementation and as a leader in sharing successful approaches with DOD counterparts.

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Appendix A

CUSTOMER REQUIREMENTS

Customer requirements are the needs and wants of the customer expressed in terms of mutually agreed upon specifications. Communication with customers should produce a list of valid requirements that are current, realistic, and measurable, that meet reasonable expectations of the customer; and that fall within corporate constraints. Requirements will generally address areas of concern like performance, conformance, durability, affordability, cost, and others. A list of typical customer requirements with definitions or qualifiers is set out below.

Accountability: Acceptance of responsibility
Accuracy: Processing correctly
Affordability: Within certain cost constraints
Availability: Probability that a system is in operable condition at the start of a mission; a function of Reliability and Maintainability; (a sample measure: the incidence of unplanned downtime (NWC 1980))
Clarity: Understandability, clearness of statements
Completeness: Thoroughness; no missing parts or information; percentage of critical issues addressed
Concern For Local Communities: Corporate sensitivity to the impact of NWC on local community resources; interaction with local governments; contribution to local charities and volunteer activities
Concern for Physical Environment: Corporate concern for land, endangered species, water, waste management, etc.
Conformance to Specifications: Degree to which design characteristics and operating characteristics meet established standards (Garvin); (sample measures: acceptable defect rates after product is in use, tolerance "stack-up" costs, Taguchi loss function)
Cost Containment: Control of costs
Cost Efficiency: Ratio of output produced per cost (Byrns)
Cost Management: Attention to the budget

Customer Safety: Provision of reasonably safe working and handling environment for the end user of NWC products

Durability: Expected product life (Garvin)

Effectiveness: Ratio of actual milestones to milestones set for a given time period (Somers)

Efficiency: Ratio of planned resources to consumed resources (Somers)

Employee Safety: Provision of relatively safe work environment

Environmental Engineering: Designing items to function in the operational environment (NWC, January1990)

Ethical Integrity: Understanding and working according to a strong set of principles and communicating these principles to all aspects of the organization and the community at large

Financial Integrity: Soundness of proper financial transactions; maintaining accounts in a way that meets the letter and spirit of accepted fiscal standards

Functional Performance: Matching products to user needs; addresses the basic functions of the product

Human Factors Engineering: Design of items to produce effective human-machine integration (Dhillon, 1986)

Innovation: Creative changes and adaptations (Somers); creative and effective engineering approaches; (sample measures: savings, generating unexpected revenue)

Maintainability: Ability to retain in (or restore to) a specified condition with prescribed maintenance (NWC, January 1990); addresses ease and speed of preventative maintenance, serviceability, repairability, availability of spare parts, etc.; (sample measures could be mean time to repair, maintenance work hours per operating hour, unscheduled downtime)

Producibility: Enables an item to be manufactured and inspected at the desired rate; reducing production costs while maintaining quality (NWC, January 1990)

Product Security: Ability to protect the product from unauthorized use or access; customer's ability to control the product after it is in use; protection of documentation, reports, and processing procedures (especially software) from direct or indirect damage or errors

Productivity: any ratio of outputs to inputs (Knudson)

Public Safety: Minimizing danger to the general public

Quality of Work Life: Health, wellness, training, career mobility, job satisfaction, open communication, etc.

Reliability: Probability that an item will perform its intended function for a specified interval under stated conditions (NWC,

January 1990); (sample measures: "infant mortality," existence of fail-safe systems, mean time between failures, mean time to first failure, failure rate per unit time, ratio of production failures to customer failures (Garvin))

Responsiveness: Ready response of NWC personnel to an appeal for aid by a customer

Support: Product-improvement support, phase-in support, operations support, and phase-out support (NWC, 1980)

Survivability: Ability to carry out a mission in a hostile environment; function of both Susceptibility and Vulnerability (NWC, 1980)

Susceptibility: Probability of damage by a threat (NWC, 1980)

Technical Flexibility: Features that supplement basic features; ability to customize to more specific user needs (Garvin); flexible technology; portability (especially in software); for example, use of off-the-shelf components

Timeliness: Promptness of delivery

Vulnerability: Extent of system degradation after subjection to threats (NWC, 1980)

Appendix B

TYPICAL MEASURES OF RESEARCH PRODUCTIVITY

The National Science Foundation routinely uses publication and patent information as a measure of research productivity and regularly reports how various segments of engineering, academic research, industrial research, etc. stand with respect to national and international standards (National Science Board). It is important to know if any of these typical measures are used by Navy or DOD agencies for awarding funds or projects, or for comparing NWC to similar organizations.

PATENT APPLICATIONS

Tracking the number of patents awarded can lead to distorted information about the time span actually represented by the efforts leading up to the application. Tracking the number of patent applications sometimes can be a better reflection of the time in which the research occurred. Also, shared patents can be a measure of cooperative research efforts. Other types of cooperative agreements can also be tracked.

PUBLICATION EFFORTS

New knowledge, the primary product of research, can be measured by various publications counts (National Science Board). External refereed (peer-reviewed) articles, other publications, and presentations (to some minimum level of audience) are all indicative of research output. For instance, tracking numbers of citations provides an indication of how much impact an individual report has on other research.

EDUCATION

The National Science Foundation tracks detailed information about the status of education in all sectors of American industry, research, and academia. This information is used to predict future R&D productivity. The Foundation also makes detailed observations about national and international trends, changes, and comparisons of groups to each other. Several potential NWC measures in this area are listed below.

Level of Education

Average education level of scientists and engineers can be an indication of the sophistication of problem solving capability.

Grade Point Average

Average grade point average (GPA) of incoming Junior Professionals can be a measure of future capability and success. (Alternative measures could be developed to identify special capabilities among those with mediocre GPAs.)

Continuing Education

Number of current education endeavors (especially in areas identified as critical) is an indication of interest level and desire for better technology. Among the areas that need continuing training are systems engineering approaches, mathematical modeling as an enhancement to one's own technical field, and statistical training to supplement TQM.

INTEGRATED APPROACHES

Integrated-discipline efforts enhance elegant problem solving, especially in software development. For example, some problems could be elegantly attacked by a small team with an engineer, a computer scientist, and an applied mathematician.

Appendix C

CRITERIA FOR CHOOSING MEASURES

TYPES OF MEASURES

Direct Measures

Direct measures are vertical measures. They directly add up numerically. Everyone measures the same units. For example, if the goal is to reduce deaths and accidents, then everyone contributes the same information: counts of deaths or accidents. Direct measures tend to be more common at high levels in an organization.

A useful example is taken from FP&L. Given the goal of restoring power quickly, employees are sent to check lines, substations, and other equipment. Different groups are contributing the same type of information, which is directly additive.

Indirect Measures

Indirect measures are horizontal in nature. These measure the effects of different activities and eventually become a system of measures that contributes effects that are cumulative, but not directly numerically additive. Indirect measures tend to be more common at group or individual activity level.

If the goal is to produce accurate bills, different groups contribute different information. For example, at FP&L, meter readers will gather information about access to meters, data gathering errors, etc., whereas accounting clerks will address issues concerning the database, training adequacy, and complications in the pricing schedule. Different groups monitor different things, but the cumulative effects are considerable when examined all together.

Auditability

Auditability means that anyone can measure the same thing in the same units. There is agreement as to the quantification of some characteristic. Quantification is tailored to the specific requirements. Information from different samples at different times can be meaningfully compared.

TOP-DOWN APPROACH

Priorities for improvement and the choice of measures should be determined at the top level of an organization, and these top-down strategic issues should be communicated throughout the organization. Therefore, sublevel measures are partially predetermined. Each sublevel either tracks a measure in the same units already or can choose what contributes indirect effects to a particular measure.

Corporate-level measures should represent a balance of in-house expertise; types of customers; and issues that surpass the customers' expertise, like business forecasting and regulatory requirements. This approach takes into account all the important factors for making decisions and setting priorities.

Consistency and Flexibility

Measures need to be consistently applied yet flexible. Measures can be tracked at the corporate level and at sublevels either in direct measures or indirect effects on a particular measure. This flexibility allows everyone to see a way to contribute to improvement. For example, if safety is the issue, some groups can count actual accidents (direct) and others can show efforts at preventing accidents (indirect).

Attitudes (pride, for example) should be anchored into an analytic measure. Employees should focus on something that affects customer satisfaction, like eliminating bottlenecks to progress. When dealing with a "local way" that seems better than the way others do business, it is important to show its efficiency and possibly get official acknowledgment. That is, a subtle way to measure the uniqueness of an organization is to track its ability to transport better methods to other groups.

General Sequence of Events

Initially, in-house expertise is used to determine what is important to the customer. Emphasis should be on defining processes within the organization and understanding functions within the matrix of interaction of events for the measures. That is, an organization should not try to benchmark itself against others too soon.

Surveying customer requirements helps to continuously refine the method of choosing measures. Management needs to communicate the evolving priorities, and all levels need to support the choice of measures to improve. The development of a good chain of related events demonstrates knowledge about what factors contribute to any measure. Occasionally, new technology contributes new measures to the system.

The priority measures evolve with changing priorities of the customers. The system of categories, activities, and measures stays basically the same after the whole system is defined, but the priority measures slowly change as results from customer surveys are integrated into the TQM measurement model. Some measures will drop out of the priority list (even though they continue to be tracked) and other measures will end up in the priority list. Many measures are tracked and each has its own set of contributing factors, but surveys of customer requirements and the NWC analysis of the results determine which measures are chosen as members of the priority list and how long they stay priorities.

Measures that are customarily tracked are sorted into short-term and long-term goals and can evolve into and out of the corporate list of priority measures of effectiveness as customer focus changes and complaints change. That is, when a priority customer requirement dictates the improvement of its best representative measure, then this measure is now in the priority list of measures of effectiveness. Short-term and long-term goals are set. When these goals are reached, the selected measure drops out of the priority list and is replaced by another that has drawn more recent customer concern. This corporate list of priority measures can be called the periodic measures of effectiveness for NWC.

This method provides a fluid, dynamic, and flexible system for choosing priority measures. Customer needs are translated into requirements. The organization defines what functions best respond to the customer requirements. Some requirements focus directly on what the customer wants, but others need to be modified. That is, customer complaints need to be translated into what can be measured and what will

contribute most to customer satisfaction. For example, FP&L customer surveys showed that customers wanted continuity of electric service. It took FP&L some time to decide that focusing efforts on reducing unplanned shutdowns contributed the most to customer satisfaction. Therefore, reducing "customer minutes interrupted" became the priority issue with FP&L.

Not all measures need improvement, but most need to be maintained at a certain level or quality of output. Avoiding complacency and maintaining processes that have already been improved is equally as important as the original improvement efforts. Maintaining established quality levels provides an additional avenue for employees to contribute to an overall quality-improvement effort.

Appendix D

SURVEYS

COMPONENTS OF A GOOD SURVEY MODEL

The first consideration when putting together a survey is a good design. Well-thought-out questions are a must, including understanding of what the question really asks and of the respondent audience that is being queried. Well-structured questions capture the right information. For example, sets of revolving questions can help establish priorities. Open-ended questions can allow the respondent to state stronger opinions. Also, open-ended questions can solicit unexpected responses that could not have been anticipated (Dillman).

The second consideration is good analysis of a survey. The procedures for processing survey data should be designed and established well before the data are collected (Dunham). Careful codifying of the results is important. It is important to understand validity and reliability of survey results. A valid question measures what it is supposed to measure, whereas the reliability of a measure is its consistency in giving the same reading (Patchen). The treatment of response errors should be understood (Jessen).

The third consideration is good documentation. Common sense dictates that good documentation is essential in any analytic investigation.

A well-designed survey can yield results that reflect overall attitudes. A good survey can demonstrate what employees think about quality-improvement efforts, what employees think about supervisors' attitudes and vice versa, and what employees think about quality of work life. Most importantly, for purposes of this report, customer attitudes about product requirements can be assessed.

The results of surveys can be used to improve products, improve customer relations, and provide a basis for direct communication between

the customer and the employee most responsible for the product characteristics. Also, studying the results can help improve the survey questions as the survey model matures. Survey results not only give immediate information about what is important to the customer, but also monitor changes in customer-satisfaction levels over time.

DEVELOPMENT, ADMINISTRATION, AND ASSESSMENT OF SURVEYS AT FP&L

Florida Power and Light prefers outside consultants for survey activity (Qualtec). FP&L helps formulate the questions, but Walker Research has the primary responsibility for the surveying activities (Walker). FP&L believes that the use of outside consultants provides a sound survey instrument and demonstrates sincerity on the part of FP&L towards customers and employees for their perspectives and opinions.

The use of outside consultants also helps eliminate the biases of internal analysts. Another benefit of employing outside consultants is that doing so provides anonymity, especially for internal employee surveys, and therefore yields much useful information. A parallel to this policy is the way in which NWC uses an outside consultant for career testing and counseling of Junior Professionals.

FP&L performs three basic types of surveys. For each, samples are selected; exhaustive surveying is not done. A customer-requirements survey is performed yearly for determining problem areas, setting goals, and choosing priority measures. Customer-satisfaction surveys are administered quarterly to give periodic assessment as to whether or not there has been improvement. Employee surveys are given once or twice a year and are three to four pages long with many simple questions. One of the areas of concern that the employee surveys are designed to assess is the employees' attitudes about organizational commitment to quality efforts.

FURTHER SOURCES OF SURVEY INFORMATION

1. Webber Group (708)-653-0583 and Standard & Associates, Inc. (312)-337-1729; Quality Climate Survey.

The two groups have combined efforts to help companies determine the level of employee receptiveness to quality improvement efforts. The

Climate Survey addresses three aspects of employee attitude: company commitment to quality, degree of employee participation, and general employee attitude. More than 50% of the survey is drawn from the SRA (Science Research Associates) Attitude Survey System, allowing companies to compare their employee responses to national norms. The Climate Survey can be used as part of quality audits, to identify areas of resistance to change, and as a quantitative means to increase the importance of quality in performance appraisal systems (*Quality Progress*, March 1990. p. 15).

2. General Research Corp, Technical Support Group, 7655 Old Springhouse Road, Mclean, Va. 22102; "Development of Productivity and Quality Self-Evaluation Audits," Report #1582-03-89-CR, September 89; authors Somers, Rouiller, Hsiao.

This report describes the development of the audit, the tests of the audit at six DOD organizations, the results of the tests, and an assessment of the audit's validity and internal reliability.

3. William H. Hendrix (Clemson University). "Development of a Contingency Model Organizational Assessment Survey for Management Consultants," for use by Air Force management consultants at the Air Force Leadership and Management Development Center (LMDC); Journal of Experimental Education, Winter 1984, pp. 95-105.

Organizational effectiveness can be considered the degree to which managerial goals are attained. The organizational assessment package was developed within a contingency model of organizational effectiveness and is a diagnostic instrument. A contingency approach to organizational effectiveness considers effectiveness to be a function of the manager, the situational environment, and the criteria of success. Criteria of organizational effectiveness include hard or objective measures (productivity, quality, efficiency, profit, growth) and attitudinal or subjective measures (morale, motivation, satisfaction). The report describes the package, survey questions, factor analysis, results, and limitations of the model.

Appendix E

ADDITIONAL MEASURES OF EFFECTIVENESS

In addition to the priority measures, the measures of effectiveness might routinely include two other measurements. Firstly, the overall percent of employee participation in the organizational suggestion system should be included. It represents the "heartbeat" of NWC. Secondly, the results of separate surveys that represent perceived customer satisfaction could be reported. These results represent the "pulse" of the customer base. Additionally, the measures of effectiveness of NWC could include the results of a general survey of employees that demonstrate the collective perception of the level of TQM implementation at NWC. These results represent the "pulse" of the employee.

Florida Power and Light believes that the degree of participation in suggestion systems represents the collective belief of individuals in the workability of the overall management system, a theory similar to some regarding individual investor participation in the stock market (Qualtec). At the corporate level, overall percent of participation is measured. Management reports reflect how teams and groups are participating compared to each other. Measuring the number of ideas per generic group is better than measuring per individual. (Although FP&L does not include this information in individual performance evaluations, the Japanese track individual participation.) Broad participation at all levels and across all disciplines represents good communication within an organization. At each sublevel, percent of participation is measured, but each level down needs to track more information about suggestions. For example, at local level and suggester level, turnaround time in responding to suggestions is important for maintaining employee faith in the effectiveness of the system.

Measuring participation in social events can be a reflection of communication at all levels and stratifications within an organization. If employees believe that supervisors participate adequately in organizational social and wellness events, then this belief can be a subtle measure of leadership.

Appendix F

CREATIVITY AND PRODUCTIVITY IN RESEARCH AND DEVELOPMENT

Any of the following processes could be defined in such a way as to identify factors that contribute to improvement efforts. The development of scoring models (trade-off studies with weighting and ranking of factors) as decision aids is also possible for any of these activities.

RESEARCH AND DEVELOPMENT MANAGEMENT

One approach to measuring R&D productivity is to evaluate how effectively R&D resources are managed. The following methods are from Szakonyi.

Ranking of Research Projects

A model needs to be in place to identify which research projects show the most promise. The best trade-off of technical versus administrative requirements for prospective projects needs to occur as objectively as possible. It is also important to have an effective method for terminating projects that are identified as probably not successful. Terminating projects should occur in a manner that captures the knowledge generated so that others do not repeat the same efforts and so that individuals are not penalized for documenting a failure (NWC, 1968).

Evaluation of Project Goals

A model needs to be in place for tracking whether projects meet technical, schedule, and cost goals. A method could be developed for weighting these efforts to assess output of research projects and identify problems. Such an evaluation encourages communication and accountability.

Case History of Projects

It is important to document the development and successful application of particular technologies. This historical information can be used to predict the future applicability of existing technology. Decisions can be made about whether or not to exploit existing technologies or develop new ones.

Evaluation of Research Issues

The state of the art of technology within an organization is important. It is also important to be aware of technological developments outside of the organization. Future needs and opportunities within the organization need to studied. It is important to have a "fast-turnaround" method for assessing space, equipment, and people needs for a new project under consideration. Examining the balance of distribution of these resources is also important. Addressing these issues would link the best potential to the most desirable goals. The National Bureau of Standards has a method for addressing some of these issues (Hall).

REPLICATION OF UNIQUE R&D EFFORTS

When an effort results in an outstanding development project, there are possibilities for defining activities in which measures could be developed.

Repeatability of the Effort

If the genius behind an effort leaves, the project should not lose its flow of effectiveness. The expert's brain power and creativity should be developed into a repeatable effort. The same group, and different groups, should be able to replicate the effort.

Transfer Genius Into a Standard

A successful research-and-development effort should be transferred into a detailed standard, so that others can learn from a creative approach. For example, if an engineer understands how not to approach something as well as how to do it, there should be a process in place so that others can take advantage of that knowledge without having to learn by repeating the same failures.

CONTINUOUS IMPROVEMENT OF R&D EFFORTS

Continuous Improvement Versus Continuous Replacement

Some NWC activities could be further defined to ensure that products are designed in such a way that continuous improvement is reasonably possible in the future. Several areas that could be considered are

- Implementing technical advances after product is in the Fleet.
- Upgrading less-than-perfect parts after a product is in use. (Even though the system as a whole is good, some parts could have suffered from lack of attention due to constraints.)
- Incorporating new technology into an older product.
- Reconfiguring good parts or subsystems into a new system with new capabilities.
- Directly communicating between the Fleet user and NWC so that needs are known and improvements are appreciated, and this appreciation is communicated directly to NWC employees.

Design Criteria Versus Operating Criteria

One important issue is to determine to what extent operating conditions supersede design and test conditions. For example, a weapon system may be designed to operate well once, but it may have to be primed to operate several times in drill situations.

Requirements Versus Restrictions

It is important to achieve the best possible trade-off between performance requirements and restrictions. For example, the application of Taguchi's robust design helps choose a reasonable set of test criteria and optimize design parameters to ensure that the product will meet the requirements of the customer and stay within constraints (Chase). A robust design (a product with characteristics that are tolerant to uncontrollable changes) can be achieved.

Improvements Versus Innovation

It is important to determine the best combination of significant improvement without technical innovation (efficiency of operation, better maintenance, better vendor selection, better documentation, etc.) versus

incorporation of new technology. This determination should be done through a systematic logical approach.

DOCUMENTATION

Documentation efforts reflect efficiency: information ends up in retrievable databases, which prevents duplication of effort. Documentation efforts reflect accountability: funding requests and expenditures are accurately described and explained. Documentation efforts reflect reliability: products may be reliable, but if problems develop, good documentation can be the key to quick resolution. Documentation efforts reflect sophistication: in addition to technical expertise, an organization needs a way to retain corporate knowledge and benchmark itself against others.

For example, at NWC the number of requests for technical publication and technical memorandum report numbers is much higher than the number of reports actually submitted to the Technical Information Department for inclusion in retrievable databases. The difference represents new technology developed at DOD expense that will probably be duplicated because a literature search will not show its existence.

Procedures at Micro-Level

Micro-level procedures could include written documentation, presentations, and training sessions. Keeping daily logs and notebooks is important.

Processes at Macro-Level

Macro-level processes such as written documentation, presentations, and training sessions help share information.

Corporate Databases

Corporate databases could be constructed that are categorized by specific topic. Scientists and engineers could search to determine what ideas have been proposed, how much development has occurred, and what processes or ideas resulted in failures, or which ideas are on the back burner because they are currently considered too advanced. Databases could also be used to construct "what if" scenarios with all of the available information.

CREATIVITY

Disposition of Ideas

One element of an R&D institution is a process or an advisory pool for identifying types of ideas and delegating responsibility for routing each idea to its best disposition. For example, part of the process could require a search to determine previous history of similar concerns, or other important information. Components of any idea system should include well-thought-out questions, good analysis (including trade-off studies), and good documentation. People who submit ideas and proposals for research projects need the resources available to help them understand and more clearly define what they are trying to say. Three basic types of ideas at NWC are

Ideas That End Up As Funding Requests for Research. An organization needs a scientific or logical system for determining which research projects best fit the overall mission and customer needs. A research organization should have a prioritizing process for assessing availability of and lead time for possible acquisition of resources for proposed research projects. This process serves as a decision aid for determining which projects to pursue. Additionally, a process should be in place for allocating people, tools, equipment, and funds among existing research projects. Both processes need to be impersonal.

Ideas That Need A Process-Improvement Team. Experts could be available, either individually or in small groups, to address important issues on short notice.

Ideas That are Candidates for the Suggestion System. This type does not need a process-improvement team. These ideas are the "just do it" kind.

Participation in R&D Consortia

A trade-off study of the advantages and disadvantages of belonging to an R&D consortium could be enlightening. Among the factors that could be addressed are types of R&D consortia, advantages and disadvantages of participation, relative effectiveness of the existing groups, and the possibility of forming one that is specific to NWC needs.

MISSION D

NWC PHILOSOPHY STATEMENT

- *Quality Is First Among Equals*
 We will commit to quality products to the Fleet by understanding our customers' expectations, providing products and services that conform to performance, cost, and schedule requirements, and continually improving our processes to ensure the most effective internal operations.
- *People are Important*
 The most important asset of the Naval Weapons Center is our people and the military, civilian, and contractor team. We will invest in training and development of our people throughout their careers; provide a stimulating environment; provide opportunity for growth, self-management, and utilization of their talents; improve the quality of their work life; and encourage mutual respect, teamwork, and a sense of community.
- *Individual Contribution*
 Each and every employee has the responsibility and obligation to actively participate in and influence the future of the Naval Weapons Center. Management has the responsibility and obligation to listen, enable, and implement.
- *Work Ethic*
 Individual and team excellence, honesty, credibility, accountability, and dedication are highly valued at the Naval Weapons Center. These traits ensure the integrity of our decisions and technical advice. Being a "China Laker" means a "can-do" attitude and "going the extra mile" to get the job done.
- *Technical and Management Innovation*
 The willingness to try new approaches and apply unique solutions is a vital element of the Naval Weapons Center's success. Creativity, innovation, and responsible risk taking are encouraged, nurtured, and rewarded to give rise to better and lower-cost weapon systems. We will continue to emphasize additional management innovations that provide our personnel with the freedom, facilities, resources, remuneration, and flexibility that are conducive to creativity.
- *Open and Effective Communication*
 Effective communication through all levels of the organization is absolutely vital to the success of the Naval Weapons Center.
- *Full-Spectrum Support*
 Our expertise covers the full range of the weapons development process from basic and applied research to prototype hardware fabrication, production support, and Fleet support. While we concentrate our efforts in enhancing the technology base and in developing and integrating new systems, we will maintain a full balance of capability that will keep us clearly in touch not only with advancing technology but also with the problems and needs of the Fleet.

NWC

The Centers mission is to be the principal Navy for air warfare systems (except antisubmar

NWC DEFINI

We carry out our vision of what we would like our orga mission elements

- Research, design, development, test, and systems in systems into strike, ASUW, and AAW aircraft
- Research, design, development, and test of tactical m
- Operation, maintenance, and improvement of a natio and evaluation
- Research, design, development, and test of parachu
- Studies of naval warfare systems for strike, ASUW, A
- Promotion and maintenance of fundamental research areas
- Operation, maintenance, and improvement of a naval RDT&E, range users, tenant activities, and surround

ANNUAL EXTERNAL QUALITY MEASURES

1.
2.
3.
4.
5.

NWC QUA

Achieve customer satisf

TOP FIVE REQUIREMENTS OF EXTERNAL CUSTOMERS

ANNUAL EXTERNAL-CUSTOMER SURVEY

CATEC

QUALITY | **DELIVERABLES** | **C**

CUSTOMER REQUIREMENT

NWC ACTIVITY | **NWC ACTIVITY**

MEASURE | **MEASURE**

MEASURE | **MEASURE**

MEASURE | **MEASURE**

CUSTOMER REQUIREMENT

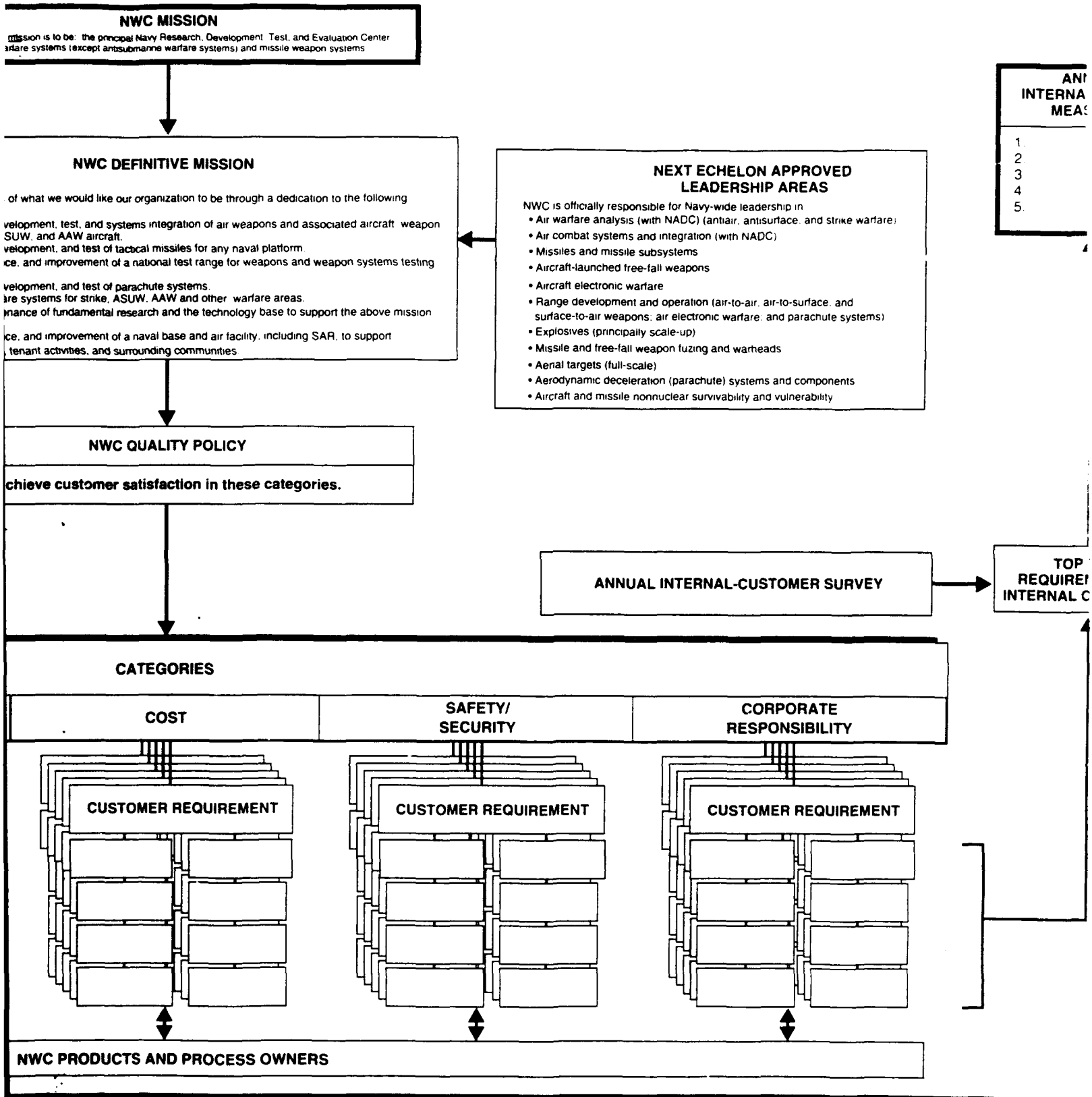
CUSTOME

NWC PRODUCTS AN

CHINA LAKE - PEOPLE COMMITTED TO EXCELL

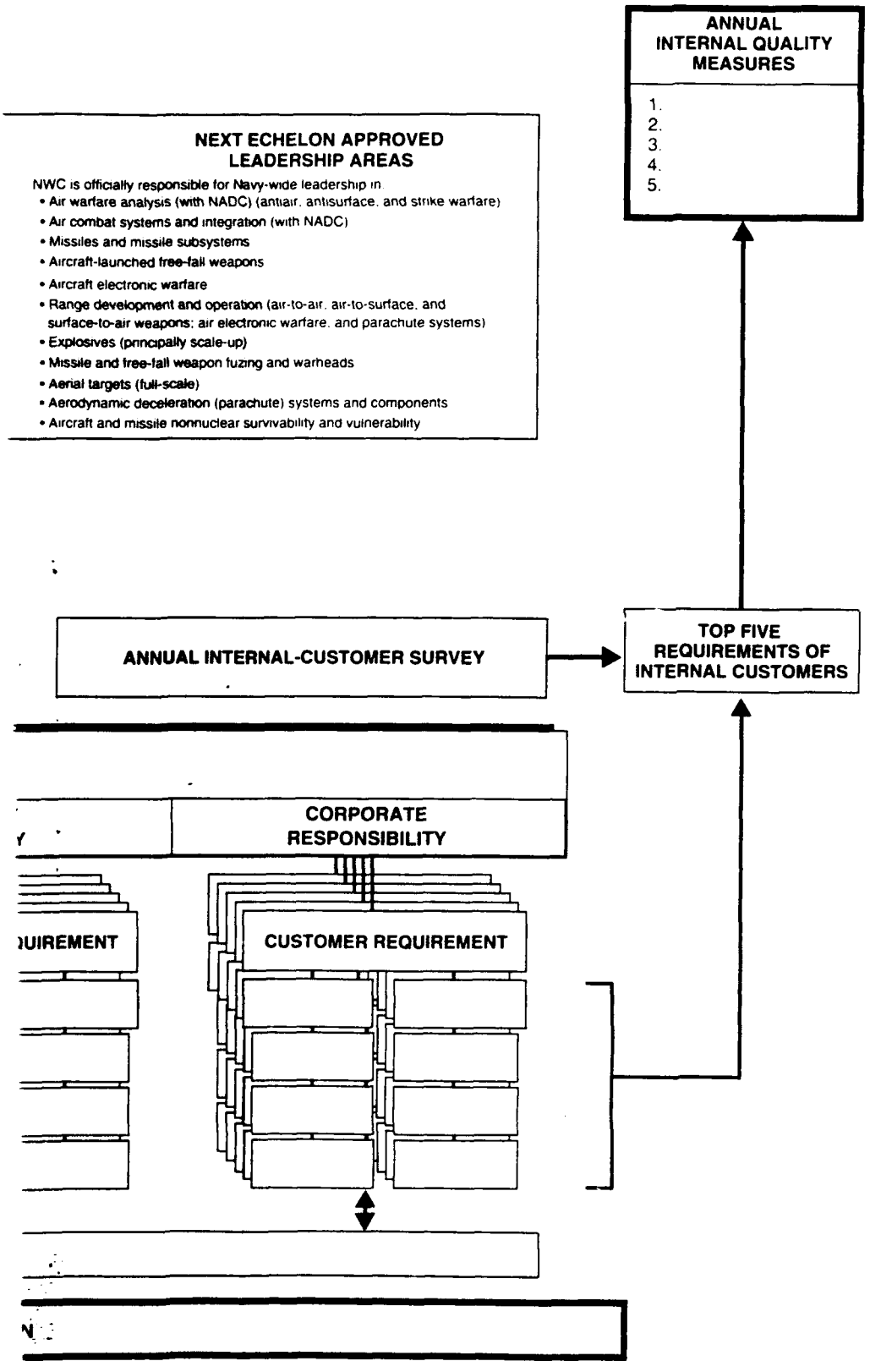
FIGURE 7. NWC Quality

MISSION DEPLOYMENT



7. NWC Quality Measurement Model.

2 of 3


ANNUAL
INTERNAL QUALITY
MEASURES
1.
2.
3.
4.
5.
NEXT ECHELON APPROVED
LEADERSHIP AREAS
NWC is officially responsible for Navy-wide leadership in
• Air warfare analysis (with NADC) (antiair, antisurface, and strike warfare)
• Air combat systems and integration (with NADC)
• Missiles and missile subsystems
• Aircraft-launched free-fall weapons
• Aircraft electronic warfare
• Range development and operation (air-to-air, air-to-surface, and surface-to-air weapons; air electronic warfare, and parachute systems)
• Explosives (principally scale-up)
• Missile and free-fall weapon fuzing and warheads
• Aerial targets (full-scale)
• Aerodynamic deceleration (parachute) systems and components
• Aircraft and missile nonnuclear survivability and vulnerability
ANNUAL INTERNAL-CUSTOMER SURVEY
TOP FIVE
REQUIREMENTS OF
INTERNAL CUSTOMERS
CORPORATE
RESPONSIBILITY
CUSTOMER REQUIREMENT